Infiltration Testing for Natural Drainage Systems in Seattle, Washington

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Keywords: Infiltration, Swales, Stormwater, Restoration, Urban, Residential

This paper presents a case history of infiltration testing for the natural drainage projects in the City of Seattle by the Seattle Public Utilities Materials Laboratory. The projects include the Street Edge Alternatives Project (S.E.A. Streets) in 1999; the Broadview Greengrid Natural Drainage Project in 2002; the Pinehurst Greengrid Natural Drainage Project in 2004; and the future Venema Greengrid Natural Drainage Project in 2006.

For the S.E.A. Streets project, the SPU Materials Laboratory utilized the 1992 Washington State Department of Ecology (DOE)'s Stormwater Management Manual for the Puget Sound Basin (Department of Ecology, 1992) to determine the infiltration rate for design. The manual provided USDA textural classification correlations and the small-scale field test, the EPA Falling Head Test. The USDA textural classification correlations provided a long-term saturated infiltration rate of 0.25 to 0.5 inches per hour and the EPA Falling Head test yielded a long-term infiltration rate of 2 inches per hour. The falling head test seemed too high based on our knowledge of the types of soils encountered. Therefore, a long-term infiltration rate of 0.25 to 0.5 inches per hour was submitted to design.

During the design phase of S.E.A. Streets and the preliminary engineering for Broadview Greengrid, a draft version of the DOE's Stormwater Management Manual for Western Washington (Department of Ecology, 2001) was published. The manual added infiltration correlations to the ASTM D422 grain size test and we therefore provided additional infiltration rates for both projects based on this test. Unfortunately, the ASTM correlation does not provide infiltration rates for soils with a D_{10} (grain size in which 10 percent of the sample is smaller) less than 0.05-mm, which was the case for the majority of the soils encountered at both the S.E.A. Streets site and the Broadview site. Therefore, we were unable to provide an accurate infiltration rate from this method.

During our testing, we have encountered two problems with the USDA and ASTM correlations. Both problems stem from the fact that the sample collected for testing is greatly disturbed. One problem is that the disturbed sample does not account for the density of the soil at the location of the swale. Second, the disturbed sample does not take into account the complex heterogeneity at the location of the swale. To account for the heterogeneity, the manual suggests taking samples from all of the various layers within the area of the swale and compiling an infiltration rate from all of the layers. Unfortunately, we found during our investigation that the layering in the field is very complex and almost impossible to account for entirely, especially in a glacially deposited setting. The manual does provide guidance as far as adding additional factors-of-safety to account for heterogeneity. However, this only accounts for the situation where the rates may be lower due to heterogeneity. We have found that the infiltration rate in the field can be higher due to heterogeneity.

As a result of the unknowns during the beginning stages of our infiltration testing, S.E.A. Streets was designed purely as a conveyance system with an infiltration rate of zero. In fact, some of the homes along the west side of the street were below street elevation and because we were concerned about flooding the basements, a couple of the swales were lined with 6-inches of clay to prevent infiltration.

During the design phase of the Broadview Greengrid, results from S.E.A. Streets started coming in. In the first year of operation, there was a 98 percent reduction in stormwater runoff when compared to the years prior to construction. Granted, this is a short-term result, but even in the short-term, it greatly exceeded our expectations. As a result, the designers for Broadview Greengrid used a long-term infiltration rate of 0.2 inches per hour.

For the Pinehurst Greengrid project, that will be built this year, we switched to full-scale testing in the field as suggested by the 2001 DOE manual. This consisted of digging a pit along the side of the roadway the approximate dimensions and depth of the proposed swales. A transducer was placed in the bottom of the pit and it was filled using a nearby fire hydrant. A transducer, which measures water pressure, was placed in the bottom of the swale. Once the pit was filled to a desired height (2 to 3 feet), the water was shut off and the transducer measured the water level drop over time. Water was added whenever the water level dropped to about 6-inches, but it was never filled above the original height. Throughout the day, the infiltration rate slowed until it became a steady rate and a saturated condition was achieved. The test took about 5 to 6 hours to reach this steady state and we were able to

conduct four at a time. The number of tests we did at one time was only limited by the number of transducers we had.

The tests yielded short-term saturated infiltration rates of 0.5 to 1.4 inches per hour. They also provided valuable information concerning the unsaturated infiltration rate during the early stages of the tests. Analyzing the unsaturated portion of the curve and the data coming from S.E.A. Streets, we questioned whether or not the long-term, saturated infiltration rates provided by the DOE manual were too conservative for the type of small scale natural drainage systems we were constructing. The swales in these systems do not have a high level of loading when compared to the infiltration ponds or drainage fields that the DOE testing when determining its long-terms infiltration rates. As a result, Pinehurst Greengrid was designed for an infiltration rate of 0.9 inches per hour.

We are now beginning the planning stages for the Venema Natural Drainage Project. We will run the full-scale tests a little different. We will record the amount of water used to reach saturation so that we can compare this to the volume of water expected in an individual swale during a design level storm event. This will allow us to analyze whether or not the ground around the swales becomes saturated during a design level storm event to the point that the long-term saturated infiltration rate as spelled out in the DOE manual is appropriate or not. We will also, run the test over several days within the same pit to better understand how the swale reacts to multiple storm events over time.

Because of the success of S.E.A. Streets, questions have surfaced as to whether or not the water from the S.E.A. Street swales is entering into the local sewer system via loose backfill around the sewer lines and possible offsets in the sewer lines themselves. To determine if the utilities are transmitting the stormwater, we will instrument the utility corridors around the Venema project with groundwater measuring devices and monitor them for a year before the project is built and continue the monitoring for years after the project is built.

Washington State Department of Ecology, 1992, Stormwater Management Manual for the Puget Sound Basin, Department of Ecology, Olympia, 91-75.

Washington State Department of Ecology, 2001, Stormwater Management Manual for Western Washington, Department of Ecology, Olympia, 99-13.